General

Guideline Title

Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine.

Bibliographic Source(s)

Le Roux P, Menon DK, Citerio G, Vespa P, Bader MK, Brophy GM, Diringer MN, Stocchetti N, Videtta W, Armonda R, Badjatia N, BÃ¶sel J, Chesnut R, Chou S, Claassen J, Czosnyka M, De Georgia M, Figaji A, Fugate J, Helbok R, Horowitz D, Hutchinson P, Kumar M, McNett M, Miller C, Naidech A, Oddo M, Olson D, O'Phelan K, Provencio JJ, Puppo C, Riker R, Robertson C, Schmidt M, Taccone F. Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Neurocrit Care. 2014 Dec;21 Suppl 2:S1-26. [161 references] PubMed

Guideline Status

This is the current release of the guideline.

This guideline meets NGC's 2013 (revised) inclusion criteria.

Recommendations

Major Recommendations

Definitions of the strength of recommendations (*strong*, *weak*) and quality of the evidence (*high*, *moderate*, *low*, *very low*) are provided at the end of the "Major Recommendations" field.

Clinical Evaluation

1. The authors recommend that assessments with either the Glasgow Coma Scale (GCS) (combined with assessment of pupils) or the Full Outline of Unresponsiveness (FOUR) score be routinely performed in comatose adult patients with acute brain injury (ABI). (*Strong recommendation, low quality of evidence*)
2. The authors recommend using the Numeric Rating Scale (NRS) 0–10 to elicit patient's self-report of pain in all neurocritical care patients wakeful enough to attempt this. (*Strong recommendation, low quality of evidence*)
3. The authors recommend in the absence of a reliable NRS patient self-report, clinicians use a behavior-based scale to estimate patient pain such as the Behavioral Pain Scale (BPS) or Critical Care Pain Observation Tool (CCPOT). (*Strong recommendation, low quality of evidence*)
4. The authors recommend use of the revised Nociception Coma Scale (NCS-R) to estimate pain for patients with severely impaired

consciousness such as vegetative state (VS) or minimally conscious state (MCS), using a threshold score of 4. (*Strong recommendation, low quality of evidence*)
5. The authors recommend monitoring sedation with a validated and reliable scale such as the Sedation-Agitation Scale (SAS) or Richmond Agitation Sedation Scale (RASS). (*Strong recommendation, low quality of evidence*)
6. The authors recommend against performing sedation interruption or wake-up tests among brain-injured patients with intracranial hypertension, unless benefit outweighs the risk. (*Strong recommendation, low quality of evidence*)
7. The authors suggest assessment of delirium among neurocritical care patients include a search for new neurologic insults as well as using standard delirium assessment tools. (*Weak recommendation, low quality of evidence*)
8. The authors recommend attention to level of wakefulness, as used in the Intensive Care Delirium Screening Checklist (ICDSC), during delirium screening to avoid confounding due to residual sedative effect. (*Strong recommendation, low quality of evidence*)

Systemic Hemodynamics

1. The authors recommend the use of electrocardiography and invasive monitoring of arterial blood pressure in all unstable or at-risk patients in the intensive care unit (ICU). (*Strong Recommendation, moderate quality of evidence*)
2. The authors recommend that hemodynamic monitoring be used to establish goals that take into account cerebral blood flow (CBF) and oxygenation. These goals vary depending on diagnosis and disease stage. (*Strong recommendation, moderate quality of evidence*)
3. The authors recommend the use of additional hemodynamic monitoring (e.g., intravascular volume assessment, echocardiography, cardiac output monitors) in selected patients with hemodynamic instability. (*Strong recommendation, moderate quality of evidence*)
4. The authors suggest that the choice of technique for assessing pre-load, after-load, cardiac output, and global systemic perfusion should be guided by specific evidence and local expertise. (*Weak recommendation, moderate quality of evidence*)

Intracranial Pressure and Cerebral Perfusion Pressure

1. Intracranial pressure (ICP) and cerebral perfusion pressure (CPP) monitoring are recommended as a part of protocol-driven care in patients who are at risk of elevated intracranial pressure based on clinical and/or imaging features. (*Strong recommendation, moderate quality of evidence*)
2. The authors recommend that ICP and CPP monitoring be used to guide medical and surgical interventions and to detect life-threatening imminent herniation; however, the threshold value of ICP is uncertain on the basis of the literature. (*Strong recommendation, high quality of evidence*)
3. The authors recommend that the indications and method for ICP monitoring should be tailored to the specific diagnosis (e.g., subarachnoid hemorrhage [SAH], traumatic brain injury [TBI], encephalitis). (*Strong recommendation, low quality of evidence*)
4. While other intracranial monitors can provide useful information, the authors recommend that ICP monitoring be used as a prerequisite to allow interpretation of data provided by these other devices. (*Strong recommendation, moderate quality of evidence*)
5. The authors recommend the use of standard insertion and maintenance protocols to ensure safety and reliability of the ICP monitoring procedure. (*Strong recommendation, high quality of evidence*)
6. Both parenchymal ICP monitors and external ventricular catheters (EVD) provide reliable and accurate data and are the recommended devices to measure ICP. In the presence of hydrocephalus, use of an EVD when safe and practical is preferred to parenchymal monitoring. (*Strong recommendation, high quality of evidence*)
7. The authors recommend the continuous assessment and monitoring of ICP and CPP including waveform quality using a structured protocol to ensure accuracy and reliability. Instantaneous ICP values should be interpreted in the context of monitoring trends, CPP, and clinical evaluation. (*Strong recommendation, high quality of evidence*)
8. While refractory ICP elevation is a strong predictor of mortality, ICP per se does not provide a useful prognostic marker of functional outcome; therefore, the authors recommend that ICP not be used in isolation as a prognostic marker. (*Strong recommendation, high quality of evidence*)

Cerebral Autoregulation

1. The authors suggest that monitoring and assessment of autoregulation may be useful in broad targeting of cerebral perfusion management goals and prognostication in ABI. (*Weak recommendation, moderate quality of evidence*)
2. Continuous bedside monitoring of autoregulation is now feasible, and the authors suggest that it should be considered as a part of multimodality monitoring (MMM). Measurement of pressure reactivity has been commonly used for this purpose, but many different approaches may be equally valid. (*Weak recommendation, moderate quality of evidence*)

Systemic and Brain Oxygenation

1. The authors recommend systemic pulse oximetry in all patients and end-tidal capnography in mechanically ventilated patients, supported by

arterial blood gases measurement. (*Strong recommendation, high quality of evidence*)

2. The authors recommend monitoring brain oxygen in patients with or at risk of cerebral ischemia and/or hypoxia, using brain tissue ($PbtO_2$) or/and jugular venous bulb oximetry ($SjvO_2$)—the choice of which depends on patient pathology. (*Strong recommendation, low quality of evidence*)
3. The authors recommend that the location of the $PbtO_2$ probe and side of jugular venous oximetry depend on the diagnosis, the type and location of brain lesions, and technical feasibility. (*Strong recommendation, low quality of evidence*)
4. While persistently low $PbtO_2$ and/or repeated episodes of jugular venous desaturation are strong predictors of mortality and unfavorable outcome, the authors recommend that brain oxygen monitors be used with clinical indicators and other monitoring modalities for accurate prognostication. (*Strong recommendation, low quality of evidence*)
5. The authors suggest the use of brain oxygen monitoring to assist titration of medical and surgical therapies to guide ICP/CPP therapy, identify refractory intracranial hypertension and treatment thresholds, help manage delayed cerebral ischemia, and select patients for second-tier therapy. (*Weak recommendation, low quality of evidence*)

Cerebral Blood Flow

1. The authors recommend transcranial Doppler ultrasonography (TCD) or transcranial color-coded duplex sonography (TCCS) monitoring to predict angiographic vasospasm after aneurysmal SAH. (*Strong recommendation, high quality of evidence*)
2. The authors suggest that trends of TCD or TCCS can help predict delayed ischemic neurological deficits due to vasospasm after aneurysmal SAH. (*Weak recommendation, moderate quality of evidence*)
3. The authors suggest that TCCS is superior to TCD in the detection of angiographically proven vasospasm after aneurysmal SAH. (*Weak recommendation, low quality of evidence*)
4. The authors suggest that TCD or TCCS monitoring can help predict vasospasm after traumatic SAH. (*Weak recommendation, very low quality of evidence*)
5. The authors suggest that a thermal diffusion flowmetry (TDF) probe may be used to identify patients with focal ischemic risk within the vascular territory of the probe. (*Weak recommendation, very low quality of evidence*)
6. The authors suggest use of a TCD screening paradigm using Lindegaard ratios or comparisons of bi-hemispheric middle cerebral artery mean velocities to improve sensitivity for identification of vasospasm-associated ischemic damage. (*Weak recommendation, low quality of evidence*)
7. The authors suggest that TDF probes used to assess ischemic risk after aneurysmal SAH should be placed in the vascular territory of the ruptured aneurysm. (*Weak recommendation, very low quality of evidence*)

Electrophysiology

1. The authors recommend electroencephalography (EEG) in all patients with ABI and unexplained and persistent altered consciousness. (*Strong recommendation, low quality of evidence*)
2. The authors recommend urgent EEG in patients with convulsive status epilepticus (cSE) that do not return to functional baseline within 60 min after seizure medication and the authors recommend urgent (within 60 min) EEG in patients with refractory SE. (*Strong recommendation, low quality of evidence*)
3. The authors recommend EEG during therapeutic hypothermia and within 24 h of rewarming to exclude nonconvulsive seizures (NCSz) in all comatose patients after cardiac arrest (CA). (*Strong recommendation, low quality of evidence*)
4. The authors suggest EEG in comatose ICU patients without an acute primary brain condition and with unexplained impairment of mental status or unexplained neurological deficits to exclude NCSz, particularly in those with severe sepsis or renal/hepatic failure. (*Weak recommendation, low quality of evidence*)
5. The authors suggest EEG to detect delayed cerebral ischemia (DCI) in comatose SAH patients, in whom neurological examination is unreliable. (*Weak recommendation, low quality of evidence*)
6. The authors suggest continuous EEG monitoring as the preferred method over routine EEG monitoring whenever feasible in comatose ICU patients without an acute primary brain condition and with unexplained impairment of mental status or unexplained neurological deficits to exclude NCSz. (*Weak recommendation, low quality of evidence*)

Cerebral Metabolism

1. The authors recommend monitoring cerebral microdialysis in patients with or at risk of cerebral ischemia, hypoxia, energy failure, and glucose deprivation. (*Strong recommendation, low quality of evidence*)
2. The authors recommend that the location of the microdialysis probe depend on the diagnosis, the type and location of brain lesions, and technical feasibility. (*Strong recommendation, low quality of evidence*)

3. While persistently low brain glucose and/or an elevated lactate/pyruvate ratio is a strong predictor of mortality and unfavorable outcome, the authors recommend that cerebral microdialysis only be used in combination with clinical indicators and other monitoring modalities for prognostication. (*Strong recommendation, low quality of evidence*)
4. The authors suggest the use of cerebral microdialysis to assist titration of medical therapies such as systemic glucose control and the treatment of delayed cerebral ischemia. (*Weak recommendation, moderate quality of evidence*)
5. The authors suggest the use of cerebral microdialysis monitoring to assist titration of medical therapies such as transfusion, therapeutic hypothermia, hypocapnia, and hyperoxia. (*Weak recommendation, low quality of evidence*)

Glucose and Nutrition

1. The authors suggest against the routine monitoring of nutritional requirements with measurement of energy expenditure by indirect calorimetry or the use of estimating equations for assessing nutritional requirements. (*Weak recommendation, low quality of evidence*)
2. The authors recognize that accurately measuring nitrogen balance is difficult, but where this is possible the authors suggest that this may be used to help assess the adequacy of nutritional support. (*Weak recommendation, very low quality of evidence*)
3. The authors suggest against the use of anthropometric measurements or serum biomarkers as a method by which to monitor the overall responsiveness of nutritional support. (*Weak recommendation, very low quality of evidence*)
4. The authors recommend against routine monitoring of gastric residuals in mechanically ventilated patients. (*Strong recommendation, high quality of evidence*)
5. The authors recommend that arterial or venous blood glucose be measured by a laboratory-quality glucose measurement immediately upon admission, to confirm hypoglycemia, and during low perfusion states for patients with acute brain injury. (*Strong recommendation, high quality of evidence*)
6. The authors recommend serial blood glucose measurements using point-of-care testing should be performed routinely during critical care after acute brain injury. (*Strong recommendation, high quality of evidence*)

Hemostasis and Hemoglobin

1. The authors recommend that monitoring hemoglobin (Hgb) should be done in all patients. (*Strong recommendation, moderate quality of evidence*)
2. The authors recommend that central laboratory methods be used for the accurate and reliable monitoring of hemoglobin and hemostatic values. (*Strong recommendation, moderate quality of evidence*)
3. Point-of-care-testing (POCT) may help identify coagulopathy or antiplatelet agent use in patients with TBI, SAH, and intracranial hemorrhage (ICH) where there is a concern for platelet dysfunction. (*Strong recommendation, moderate quality of evidence*)
4. POCT may be used to monitor the response to interventions intended to improve platelet function. (*Weak recommendation, very low quality of evidence*)
5. In patients who require neurosurgical intervention, a detailed family history and structured screening about bleeding disorders and bleeding after traumatic events, should be elicited. (*Strong recommendation, moderate quality of evidence*)
6. Determination of time of last ingested dose, renal function, age, and other medications ingested is recommended to assist in determination of plasma concentration of the new anticoagulants. (*Strong recommendation, high quality of evidence*)
7. The authors suggest that, if available, new specific assays for the new oral anticoagulants be used to assess coagulation status in neurologic emergencies. (*Weak recommendation, low quality of evidence*)
8. In patients with liver failure, routine tests of coagulation may not accurately reflect hemostatic balance. Advanced tests of coagulation, point-of-care devices, and consultation with a hematologist are suggested. (*Weak recommendation, low quality of evidence*)

Temperature and Inflammation

1. In patients with acute neurological injury, the authors recommend continuous monitoring of temperature when feasible and, at least hourly if not feasible. (*Strong recommendation, low quality of evidence*)
2. The authors recommend that temperature monitoring alone cannot be used as a tool to discriminate infectious fever from central or neurogenic fever. (*Strong recommendation, low quality of evidence*)
3. The authors recommend monitoring core body temperature as a surrogate of brain temperature unless brain temperature is available from devices placed for other reasons. (*Strong recommendation, low quality of evidence*)
4. The authors recommend hourly monitoring for shivering with the Bedside Shivering Assessment Scale (BSAS) during therapeutic temperature modulation. (*Strong recommendation, moderate quality of evidence*)
5. The authors suggest daily measurement of blood leukocyte counts in patients with SAH who are at risk for delayed deterioration. (*Weak recommendation, low quality of evidence*)
6. The authors suggest against monitoring routine ventricular fluid white blood cell (WBC) counts to discriminate whether patients with EVDs

have infection. (*Weak recommendation, low quality of evidence*)
7. The authors suggest against monitoring inflammatory mediators routinely. (*Weak recommendation, low quality of evidence*)
8. The authors suggest monitoring brain temperature when such a device is placed for other reasons. (*Weak recommendation, low quality of evidence*)

Cellular Damage and Degeneration

1. In comatose post-cardiac hypoxic-ischemic encephalopathy (HIE) patients not treated with therapeutic hypothermia (TH), the authors suggest the use of serum neuron specific enolase (NSE) in conjunction with clinical data for neurologic prognostication. (*Weak recommendation, moderate quality of evidence*)
2. The authors recommend against the use of serum NSE for prognostication in HIE treated with TH. (*Strong recommendation, moderate quality of evidence*)
3. The authors recommend against the routine use of molecular biomarkers for outcome prognostication in acute ischemic stroke (AIS), SAH, ICH, or TBI. (*Strong recommendation, low quality of evidence*)

ICU Processes of Care and Quality Assurance

1. The authors recommend that critically ill patients with acute brain injury be managed either in a dedicated neurocritical care unit or by clinical teams with expertise in neurocritical care. (*Strong recommendation, moderate quality of evidence*)
2. The authors recommend implementation of and monitoring adherence to evidence-based protocols, in the neurocritical care population. (*Strong recommendation, moderate quality of evidence*)
3. The authors recommend that the incidence of ventriculostomy related infections may be a useful indicator of quality of care (*Strong recommendation, moderate quality of evidence*)
4. The authors recommend that use of protocols for moderate glycemic control is a useful indicator of quality of care in neurocritical care patient populations. (*Strong recommendation, moderate quality of evidence*)
5. The authors suggest that other known ICU processes of care including pressure ulcers, central line-associated blood stream infections, and catheter-associated-urinary tract infections may be useful as indicators of general intensive care, but none are specific indicators of quality in the neurocritical care population. (*Weak recommendation, low quality of evidence*)
6. The authors suggest that ventilator-associated pneumonia should not be regarded as a quality indicator in the neurocritical care population. (*Weak recommendation, low quality of evidence*)

Multimodality Monitoring: Informatics, Data Integration, Display, and Analysis

1. The authors recommend utilizing ergonomic data displays that present clinical information in a sensible uncomplicated manner to reduce cognitive load and improve judgments of clinicians. (*Strong recommendation, moderate quality of evidence*)
2. The authors suggest using clinical decision support tools such as algorithms that automatically process multiple data streams with the results presented on a simple, uncomplicated display. (*Weak recommendation, moderate quality of evidence*)
3. The authors recommend adopting a database infrastructure that enables the integration of high-resolution physiologic data (including EEG recordings) with lower resolution data from laboratory and electronic health care systems. (*Strong recommendation, low quality of evidence*)
4. The authors recommend following an iterative, human-centered design methodology for complex visualization displays to avoid adversely affecting clinical decision making. (*Strong recommendation, moderate quality of evidence*)
5. The authors recommend that device manufacturers utilize data communication standards including time synchronization on all devices to improve usability of its data. (*Strong recommendation, low quality of evidence*)
6. The authors recommend adopting "smart" alarms in the ICU to help address alarm fatigue. (*Strong recommendation, low quality of evidence*)

Monitoring in Emerging Economies

1. The authors recommend that collaborative multi-center studies are needed to address the differences in patients baseline characteristics. (*Strong recommendation, moderate quality of evidence*)
2. The authors recommend that comparative studies must control for differences in patient baseline characteristics and comparison between high-income countries (HICs) and low- and middle-income countries (LAMICs) should be made only where there is sufficient data about classification, case selection, and clinical outcome assessment. (*Strong recommendation, low quality evidence*)
3. The authors recommend that guidelines for monitoring neurocritical care patients for emerging economies should consider regional variations and recommendations for monitoring where these do not currently exist must be carefully considered. (*Strong recommendation, moderate quality evidence*)

4. The authors recommend that ICP monitoring should be used preferably where there is neurocritical care clinical expertise and in an appropriate intensive care setting. (*Strong recommendation, moderate quality evidence*)
5. The authors recommend that the role and cost/benefit ratio of MMM in individual LAMICs, and also HICs, must be weighed against the overall priorities for delivering basic health care at individual centers. (*Strong recommendation, low quality evidence*)

Definitions

Quality of Evidence

High Quality - Further research is very unlikely to change confidence in the estimate of effect.

Moderate Quality - Further research is likely to have an important impact on confidence in the estimate of effect and may change the estimate.

Low Quality - Further research is very likely to have an important impact on confidence in the estimate of effect and is likely to change the estimate.

Very Low Quality - Any estimate of effect is very uncertain.

Strength of Recommendations

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system classifies recommendations as strong or weak, according to the balance among benefits, risks, burden, and cost, and according to the quality of evidence. Keeping those components separate constitutes a crucial and defining feature of this grading system. An advantage of the GRADE system is that it allows for strong recommendations in the setting of lower quality evidence and therefore is well suited to the intended monitoring questions. Recommendations are stated as either strong ("the authors recommend") or weak ("the authors suggest") and based on the following:

- The trade-offs, taking into account the estimated size of the effect for the main outcomes, the confidence limits around those estimates, and the relative value placed on each outcome
- Quality of the evidence
- Translation of the evidence into practice in a specific setting, taking into consideration important factors that could be expected to modify the size of the expected effects.

Clinical Algorithm(s)

None provided

Scope

Disease/Condition(s)

Disorders that require neurocritical care

Guideline Category

Evaluation

Management

Risk Assessment

Screening

Clinical Specialty

Anesthesiology

Critical Care

Emergency Medicine

Neurological Surgery

Neurology

Nursing

Intended Users

Advanced Practice Nurses

Hospitals

Nurses

Other

Pharmacists

Physician Assistants

Physicians

Guideline Objective(s)

To provide evidence-based recommendations about monitoring in neurocritical care patients, and to base these recommendations on rigorously evaluated evidence from the literature

Note: This review does not make recommendations about treatment, imaging, and intraoperative monitoring.

Target Population

Adult patients with acute neurological disorders that require intensive care management

Interventions and Practices Considered

1. Clinical evaluation (use of coma scales, pain scales, sedation scales, delirium scales, sedation strategies)
2. Hemodynamic monitoring
3. Monitoring of intracranial pressure (ICP) and cerebral perfusion pressure (CCP)
4. Monitoring of cerebral autoregulation
5. Monitoring of systemic and brain oxygenation
6. Monitoring of cerebral blood flow (transcranial Doppler ultrasonography [TCD], transcranial color-coded duplex sonography [TCCS])
7. Electroencephalography (EEG)
8. Monitoring cerebral metabolism (cerebral microdialysis)
9. Monitoring of nutrition and glucose
10. Monitoring hemostasis and hemoglobin
11. Monitoring of temperature (brain and core body) and inflammation
12. Monitoring biomarkers of cellular damage and degeneration (neuron specific enolase [NSE])
13. Intensive care unit (ICU) processes of care and quality assurance
14. Multimodality monitoring: informatics integration, display and analysis
15. Consideration of monitoring technologies/neurocritical care in emerging economies

Major Outcomes Considered

- Clinical utility, validity, reliability, accuracy, and safety of monitoring tools and instruments
- Morbidity
- Mortality
- Neurological and other clinical outcomes
- Availability of monitoring techniques
- Cost-effectiveness

Methodology

Methods Used to Collect/Select the Evidence

Searches of Electronic Databases

Description of Methods Used to Collect/Select the Evidence

Note from the National Guideline Clearinghouse (NGC): A series of systematic reviews was undertaken to address each topic in this consensus statement (see the "Availability of Companion Documents" field).

The authors assigned to each topic performed a critical literature review with the help of a medical librarian according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The review period included January 1980–September 2013 and was limited to clinical articles that included more than five subjects and were published in English. The focus was on adult patients and brain disorders.

Refer to the individual systematic reviews for details regarding search strategies and databases searched.

Number of Source Documents

Refer to the systematic reviews and evidentiary tables for details regarding the number of source documents for each topic addressed in this consensus statement (see the "Availability of Companion Documents" field).

Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

Rating Scheme for the Strength of the Evidence

Quality of Evidence

High Quality - Further research is very unlikely to change confidence in the estimate of effect.

Moderate Quality - Further research is likely to have an important impact on confidence in the estimate of effect and may change the estimate.

Low Quality - Further research is very likely to have an important impact on confidence in the estimate of effect and is likely to change the estimate.

Very Low Quality - Any estimate of effect is very uncertain.

Methods Used to Analyze the Evidence

Review of Published Meta-Analyses

Description of the Methods Used to Analyze the Evidence

Note from the National Guideline Clearinghouse (NGC): A series of systematic reviews was undertaken to address each topic in this consensus statement (see the "Availability of Companion Documents" field).

The literature findings were summarized in tables (see the "Availability of Companion Documents" field).

The quality of the data was assessed and recommendations developed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system (see the "Rating Scheme for the Strength of the Evidence" field).

Methods Used to Formulate the Recommendations

Expert Consensus (Consensus Development Conference)

Description of Methods Used to Formulate the Recommendations

Representatives of the Neurocritical Care Society (NCS) and European Society of Intensive Care Medicine (ESICM) respectively chaired the review and recommendation process. Experts from around the world in the fields of neurosurgery, neurocritical care, neurology, critical care, neuroanesthesiology, nursing, pharmacy, and informatics were recruited on the basis of their expertise and publication record related to each topic. Two authors were assigned to each topic and efforts were made to ensure representation from different societies, countries, and disciplines. The review and recommendation process, writing group, and topics were reviewed and approved by the NCS and ESICM. A jury of experienced neurocritical care clinicians (physicians, a nurse, and a pharmacist) was selected for their expertise in clinical investigation and development of practice guidelines.

The literature findings were summarized in tables and an initial summary that included specific recommendations was prepared. The chairs, co-chairs, and jury members, each assigned to specific topics as a primary or secondary reviewer, reviewed these drafts. The quality of the data was assessed and recommendations developed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system (see the "Rating Scheme for the Strength of the Evidence" and "Rating Scheme for the Strength of the Recommendations" fields).

Each topic was presented and discussed at a 2-day conference in Philadelphia held on September 29-30, 2013. The chairs, co-chairs, jury, and each author attended the meeting. In addition representatives from each of the endorsing organizations were invited and 50 additional attendees with expertise in neurocritical care were allowed to register as observers. Industry representatives were not allowed to participate. Each author presented a summary of the data and recommendations to the jury and other participants. Presentations were followed by discussion focused on refining the proposed recommendations for each topic. Approximately one-third of the conference time was used for discussion. The jury subsequently held several conference calls, and then met again at a subsequent 2-day meeting to review and abstract all manuscripts and finalize the summary consensus statement presented here. They reviewed selected key studies, the recommendations made by the primary reviewers, and the discussion that took place at the conference. Strong consideration was given to providing guidance and recommendations for bedside neuromonitoring, even in the absence of high quality data.

Rating Scheme for the Strength of the Recommendations

Strength of Recommendations

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system classifies recommendations as strong or weak, according to the balance among benefits, risks, burden, and cost, and according to the quality of evidence. Keeping those components separate constitutes a crucial and defining feature of this grading system. An advantage of the GRADE system is that it allows for strong recommendations in the setting of lower quality evidence and therefore is well suited to the intended monitoring questions. Recommendations are stated as either strong ("the authors recommend") or weak ("the authors suggest") and based on the following:

- The trade-offs, taking into account the estimated size of the effect for the main outcomes, the confidence limits around those estimates, and the relative value placed on each outcome
- Quality of the evidence

- Translation of the evidence into practice in a specific setting, taking into consideration important factors that could be expected to modify the size of the expected effects.

Cost Analysis

The use of intracranial pressure (ICP) monitors was associated with more efficient care, which may prove to be important in cost-effective care in a resource-limited environment. Furthermore, ICP monitoring may help reduce the frequency of potentially inappropriate ICP-lowering therapies. There is indirect evidence to support aggressive management for severe traumatic brain injury (TBI) in low- and middle-income countries (LAMICs), including the use of advanced monitoring. Decision analysis suggests that this can be associated with cost-effective outcome enhancement.

Method of Guideline Validation

External Peer Review

Description of Method of Guideline Validation

The recommendations for monitoring are based on a systematic literature review, a robust discussion during the consensus conference about the interpretation of the literature, the collective experience of the members of the group, and review by an impartial, international jury.

Evidence Supporting the Recommendations

Type of Evidence Supporting the Recommendations

The type of supporting evidence is identified and graded for each recommendation (see the "Major Recommendations" field).

Benefits/Harms of Implementing the Guideline Recommendations

Potential Benefits

Appropriate monitoring of patients with neurological disorders who require critical care

Potential Harms

- Multimodal monitoring generates an enormous amount of data, including written, ordinal, continuous, and imaging data, in the typical patient with a neurologic disorder in the intensive care unit (ICU). Clinicians may be confronted with more than 200 variables when evaluating a patient, with the risk of "information overload" that can lead to preventable medical errors.
- "Wake-up tests" in patients with unstable intracranial hypertension pose significant risks and often may lead to physiological decompensation, and show no proven benefits in terms of in duration of mechanical ventilation, length of ICU and hospital stay, or mortality.

Qualifying Statements

Qualifying Statements

The intent of this consensus statement is to assist clinicians in decision-making. However, the authors recognize that this information must be targeted to the specific clinical situation in individual patients on the basis of clinical judgment and resource availability. The authors therefore recognize that, while the recommendations provide useful guidance, they cannot be seen as mandatory for all individual clinician-patient

interactions.

Caveats and Limitations to the Process

The setting of these recommendations, monitoring, makes it difficult to use all of the normal considerations used to make decisions about the strength of recommendations, typically of a treatment, which include the balance between desirable and undesirable effects, estimates of effect based on direct evidence, and resource use since monitoring has no proximate effects on outcome. Instead it typically modifies treatment and can only influence outcome through such modulation. The guideline authors' confidence in the estimate of effects in most analyses was not derived from methodologically rigorous studies, because few such studies exist, but often driven by epidemiological studies and investigations of clinical physiology, which usually provided indirect evidence, with several potential confounders.

Given these limitations, decisions on recommendations are driven by an expectation of values and preferences. Given the limited outcome data of both benefit and harm associated with neuromonitoring, the authors relied on inferences from observational studies and extrapolation from pathophysiology to estimate the effect and effect size of potential benefit and harm. The authors concluded that the avoidance of permanent neurological deficit would be the dominant driver of patient choice. Given that the diseases and disease mechanisms caregivers monitor are known to be damaging, and given that the time available for intervention is limited, the authors made these extrapolations unless there was real concern about benefit or evidence of harm. This approach to deciding on recommendations was universally adopted by all members of the multispecialty, multidisciplinary, multinational panel. Though there was some variation in initial opinions, careful consideration of the available evidence and options resulted in relatively tightly agreed consensus on recommendations.

Implementation of the Guideline

Description of Implementation Strategy

An implementation strategy was not provided.

Implementation Tools

Slide Presentation

For information about availability, see the *Availability of Companion Documents* and *Patient Resources* fields below.

Institute of Medicine (IOM) National Healthcare Quality Report Categories

IOM Care Need

Getting Better

Living with Illness

IOM Domain

Effectiveness

Identifying Information and Availability

Bibliographic Source(s)

Le Roux P, Menon DK, Citerio G, Vespa P, Bader MK, Brophy GM, Diringer MN, Stocchetti N, Videtta W, Armonda R, Badjatia N, BÃ¶sel J, Chesnut R, Chou S, Claassen J, Czosnyka M, De Georgia M, Figaji A, Fugate J, Helbok R, Horowitz D, Hutchinson P, Kumar M, McNett M, Miller C, Naidech A, Oddo M, Olson D, O'Phelan K, Provencio JJ, Puppo C, Riker R, Robertson C, Schmidt M, Taccone F. Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Neurocrit Care. 2014 Dec;21 Suppl 2:S1-26. [161 references] PubMed

Adaptation

Not applicable: The guideline was not adapted from another source.

Date Released

2014 Dec

Guideline Developer(s)

European Society of Intensive Care Medicine - Professional Association

Neurocritical Care Society - Medical Specialty Society

Source(s) of Funding

Neurocritical Care Society

Guideline Committee

International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care

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Electrophysiology: Jan Claassen, Paul Vespa

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Nutrition and Glucose: Neeraj Badjatia, Paul Vespa

Hemostasis and Hemoglobin: Andrew Naidech, Monisha Kumar

Temperature and Inflammation: Javier Provencio, Neeraj Badjatia

Biomarkers of Cellular Damage and Degeneration: Sherry Chou, Claudia Robertson

ICU Processes of Care and Quality Assurance: Molly McNett, David Horowitz

Multimodality Monitoring Informatics, Integration and Display, Analysis: Michael Schmidt, Michael DeGeorgia

Monitoring in Emerging Economies: Anthony Figaji, Corina Puppo

Future Directions and Emerging Technologies: Peter Le Roux, Paul Vespa and David Menon

Financial Disclosures/Conflicts of Interest

Each author and each member of the jury reported any potential conflicts of interest (COI). The author and Neurocritical Care Society (NCS) Guideline Committee Chairs determined any required resolutions according to NCS COI process and resolution guidelines before appointment to the writing committee. The following methods were used to resolve any potential COI: (1) Perform peer review for evidence-based content, (2) provide faculty with alternate topic, (3) provide alternate faculty for specific topics, (4) limit content to evidence with no recommendations, (5) perform review of all materials associated with the activity by planning committee, (6) abstain from discussions related to the conflict, (7) abstain from voting related to the conflict, (8) request reassignment to a committee that will not result in a conflict. NCS Guidelines state: "The chair or co-chairs cannot have any financial or other important conflicts of interest related to the guideline topic." Peter Le Roux proposed the subject and initiated the project and therefore was appointed chair by the NCS. To be compliant with NCS Guidelines he did not vote on any of the recommendations that followed jury deliberations because of potential COI associated with industry relationships.

Peter Le Roux receives research funding from Integra Lifesciences, Neurologica, the Dana Foundation, and the National Institutes of Health (NIH); is a consultant for Integra Lifesciences, Codman, Synthes, and Neurologica; and is a member of the scientific advisory board of Cerebrotech, Brainsgate, Orsan, and Edge Therapeutics.

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Guideline Endorser(s)

Latin American Brain Injury Consortium - Nonprofit Organization

Society of Critical Care Medicine - Professional Association

Guideline Status

This is the current release of the guideline.

This guideline meets NGC's 2013 (revised) inclusion criteria.

Guideline Availability

Electronic copies: Available from the Neurocritical Care Society (NCS) Web site .

Availability of Companion Documents

The following are available:

- Le Roux P, Menon DK, Citerio G, Vespa P, Bader MK, Brophy GM, Diringer MN, Stocchetti N, Videtta W, Armonda R, Badjatia N, Böesel J, Chesnut R, Chou S, Claassen J, Czosnyka M, De Georgia M, Figaji A, Fugate J, Helbok R, Horowitz D, Hutchinson P, Kumar M, McNett M, Miller C, Naidech A, Oddo M, Olson D, O'Phelan K, Provencio JJ, Puppo C, Riker R, Robertson C, Schmidt M, Taccone F. Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Evidentiary tables. 2014 Dec;21(suppl 2):S297-361. Electronic copies: Available from the Neurocritical Care Society (NCS) Web site .
- Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Systematic reviews. 2014 Dec. Electronic copies: Available from the Neurocritical Care Journal Web site .
- Consensus summary statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care: a statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Slide presentation. 2014 Sep 11. 20 p. Electronic copies: Available from the NCS Web site .

Patient Resources

None available

NGC Status

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